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Overview and Application of the Water Security Toolkit (WST)

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United States Environmental Protection Agency

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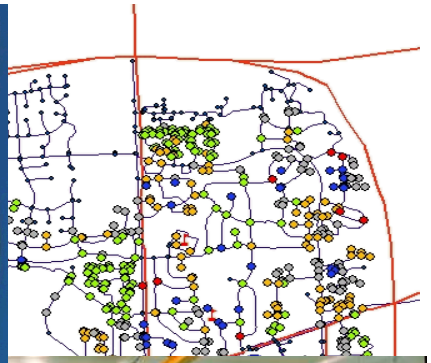
Outline

- Background
- Application
- Summary



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Motivation for Water Security Toolkit

- Water distribution systems are vulnerable to intentional or accidental contamination through multiple points of access
- Numerous contaminants could be used to cause severe public health consequences and significant economic impacts
- Water utility decision makers need state of the art tools to help detect and mitigate the consequences of contamination

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Objective of the Water Security Toolkit

- To integrate a suite of cutting-edge, automated modeling, simulation, and optimization tools into a user friendly software tool in order to support rapid and effective water utility decision making
  - Based upon EPANET
  - Simulate and obtain results for individual networks
  - State-of-art optimization routines
    - Linear programming
    - Network solver

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Intended Use of Water Security Toolkit

- Plan for response to natural disasters and terrorist attacks and compare response actions
  - Develop consequence management plans
  - Inform large-scale exercises/training
- Plan for response to traditional utility challenges (pipe breaks, water quality problems, …)
  - Evaluate implications of different response strategies
- For utilities with modeling expertise, optimize and implement response actions in real-time
  - Use data from CANARY, sensor stations, field investigations

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Water Security Toolkit (WST)

- Current capabilities in WST will help to identify
  - Consequences of contamination incidents
  - Best sensor locations to detect contamination
  - Origin of contamination in network
  - Best hydrants to flush out contaminated water
  - Best injection location of chlorine to inactivate contaminant

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Application of WST

- Use WST capabilities to identify the best response strategies following positive detection of contamination
  - Source(s) of the contamination
  - Locations to flush contaminated water
  - Locations to take grab samples to reduce the number of possible sources

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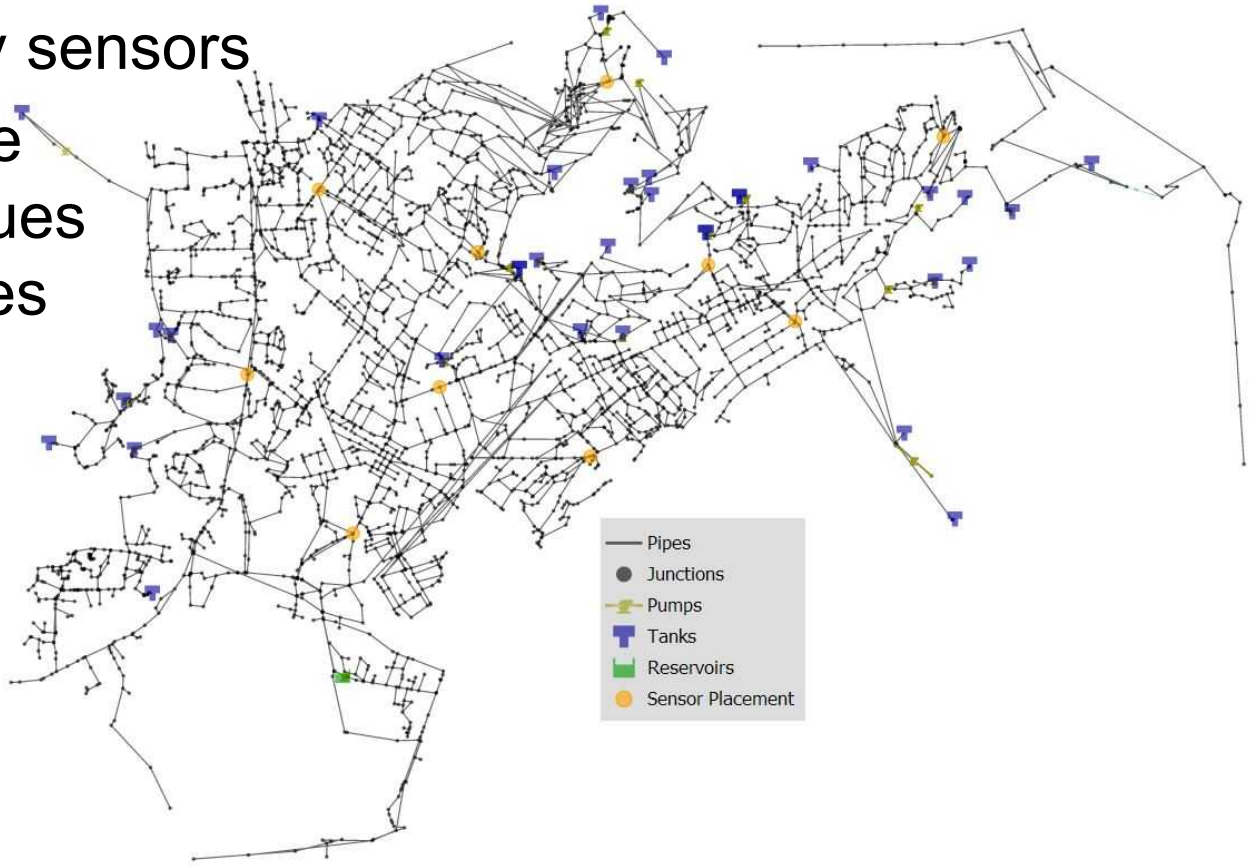
Example Network

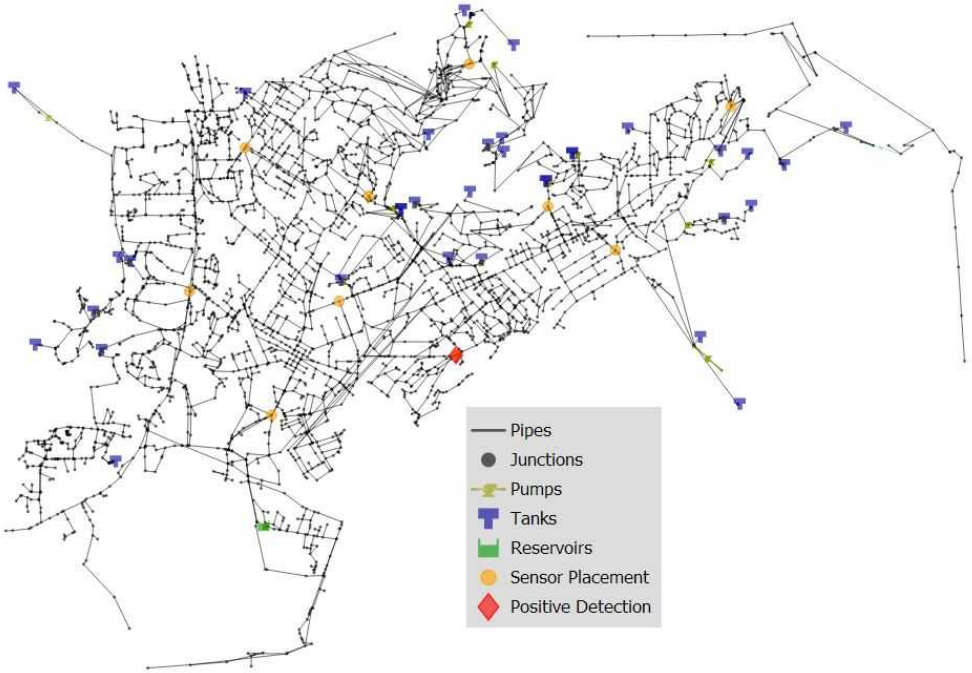
- Water quality sensor layout designed using WST
- 10 water quality sensors
- Sensors provide binary (0/1) values every 15 minutes



10:15 AM

Notification of Contamination

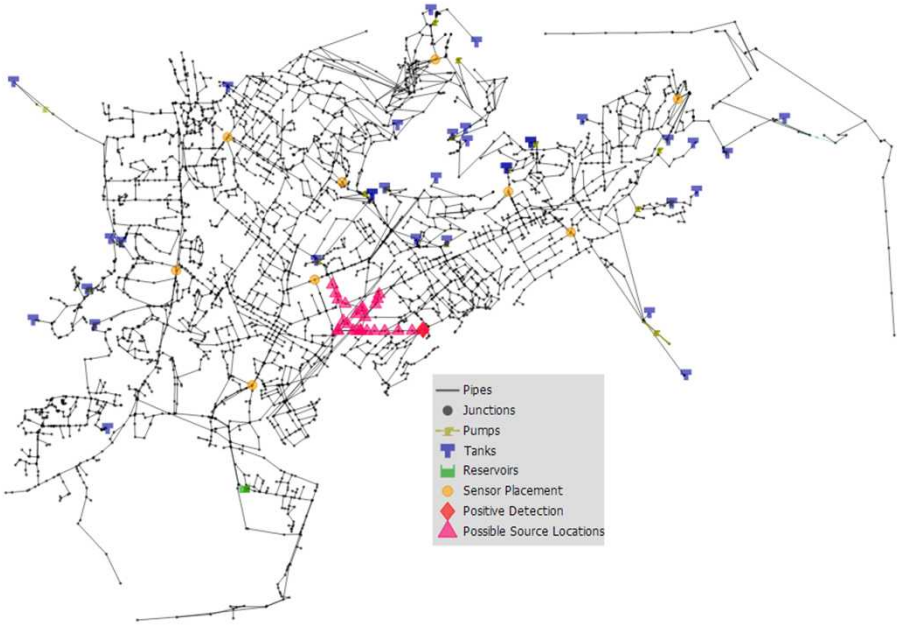
- Sensor at JUNCTION-1617 indicates a positive signal for contamination at 10:15 AM
- As more sensor data arrives every 15 minutes, the water utility staff must decide on how to proceed and/or respond to the alarm



11:00 AM

Identification Contamination Origin

- Utility staff decides to use source identification techniques to identify the source of the contamination
- With the sensor results from the past 35 hours, 25 possible sources are identified



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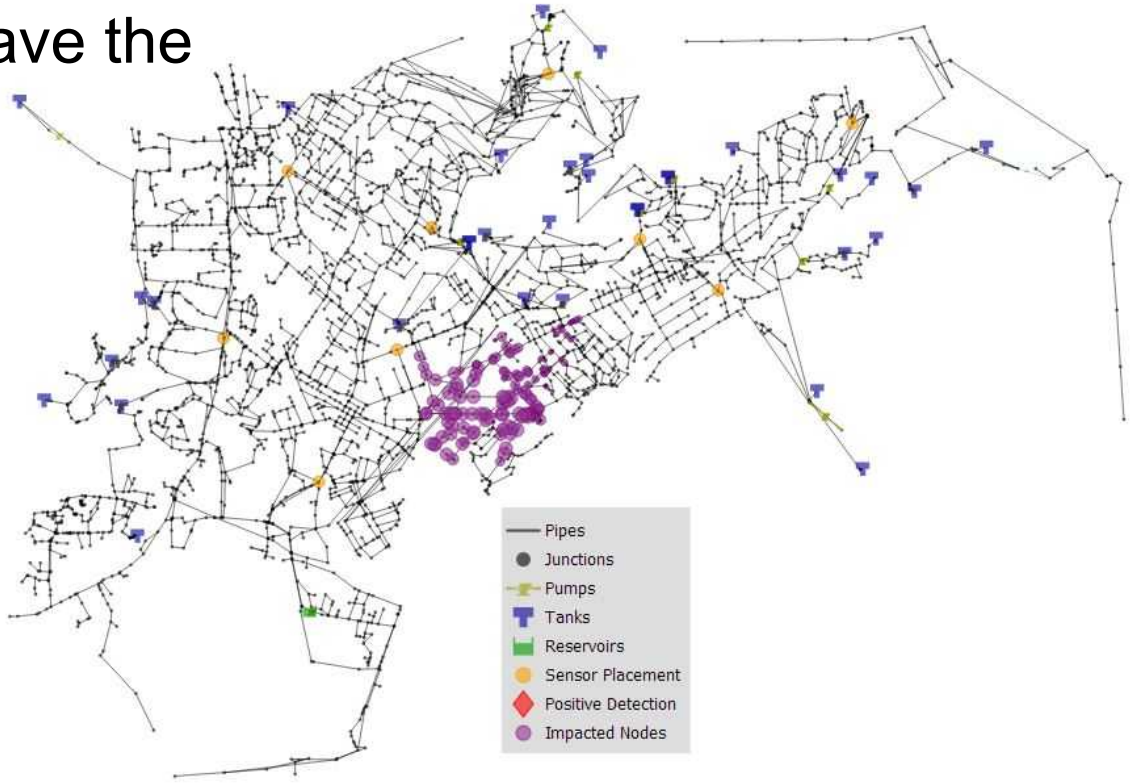
11:10 AM

Selection of Solver Initial Points

- Simulate possible sources to identify nodes which have a positive concentration at the start of flushing
- Select nodes that have the greatest combined concentration over all possible source scenarios as initial starting points for flushing solver



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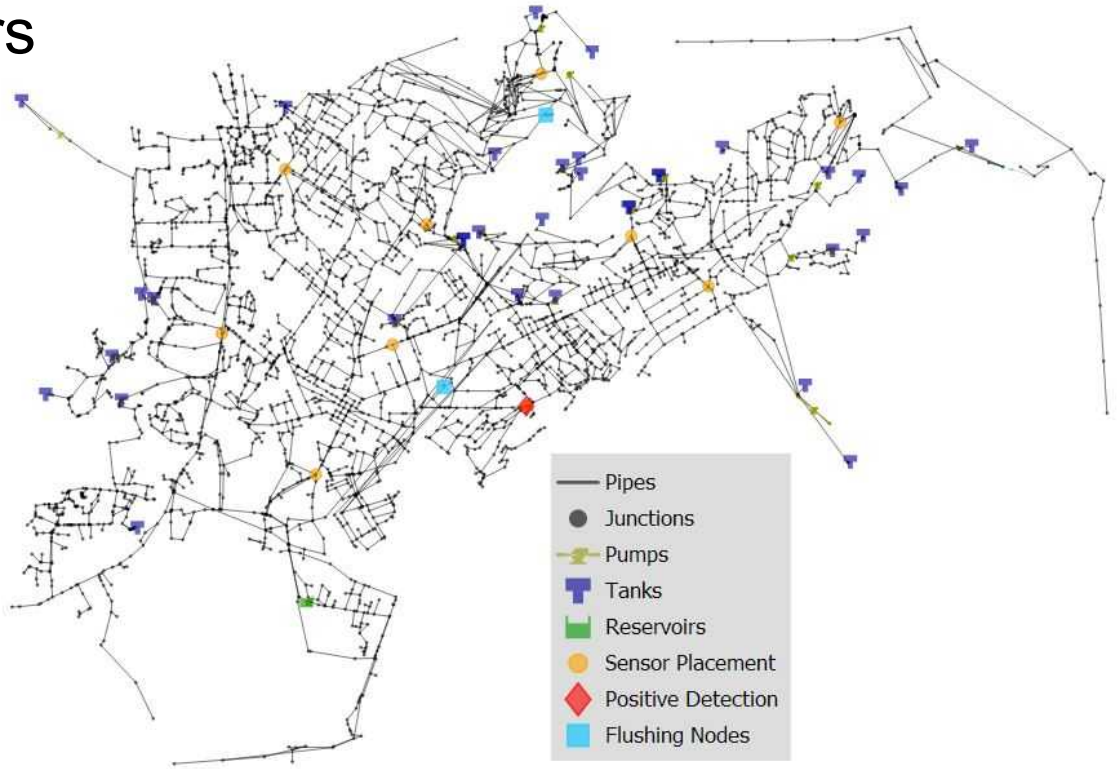
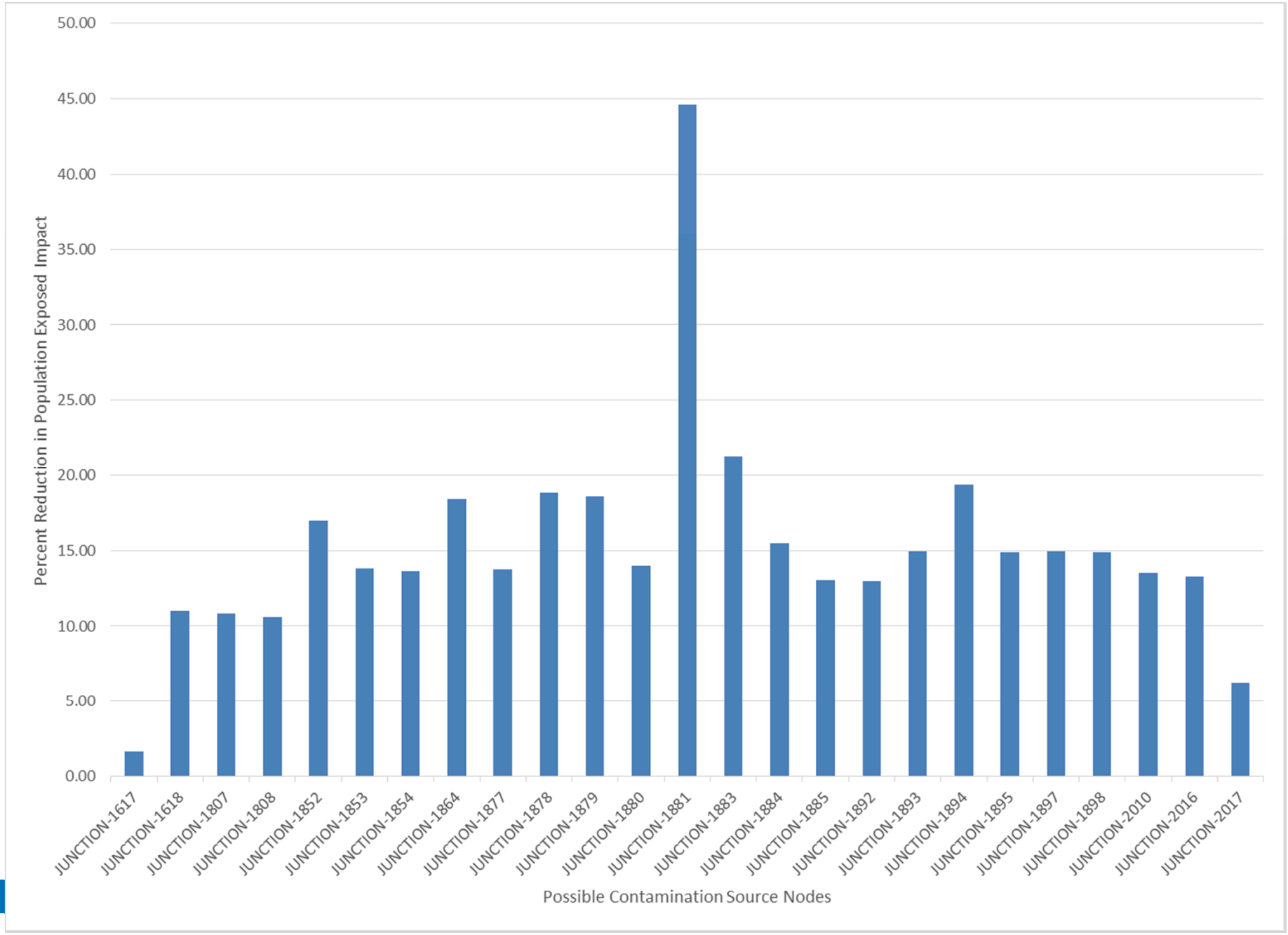
12:00 AM

Identification of Flushing Hydrants

- Flushing locations selected were JUNCTION-1876 and JUNCTION-1881 based upon flushing at a rate of 1100 gpm for 8 hours
- Almost two hours after detection, the water utility staff open up hydrants to begin flushing

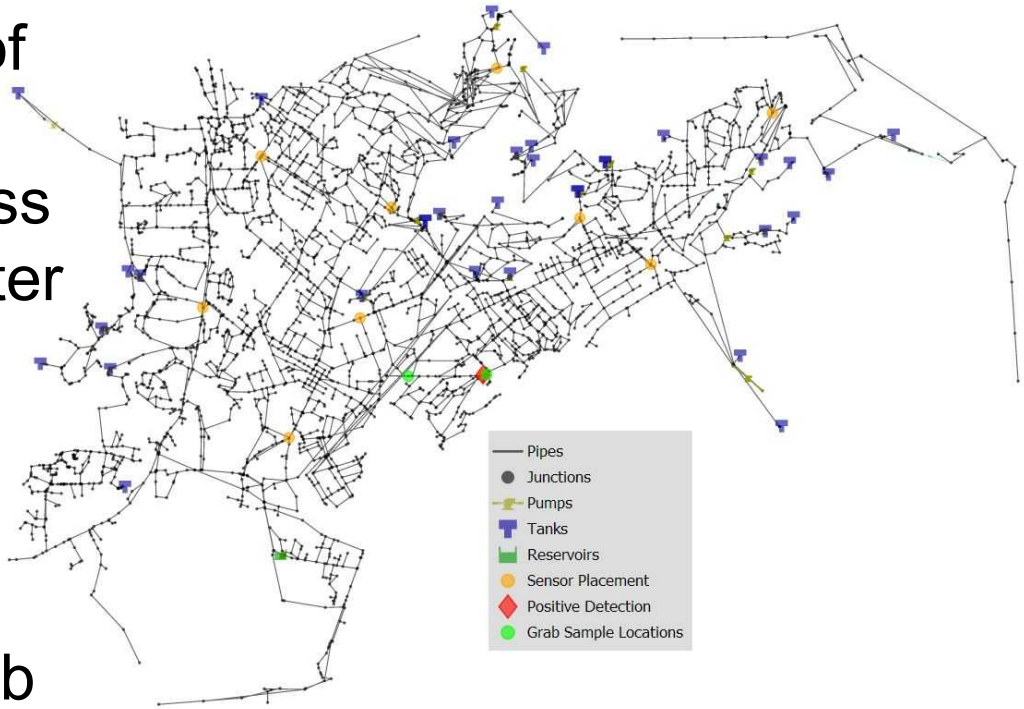



50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Percent Reduction in Population Exposed Impact
JUNCTION-1617
JUNCTION-1618
JUNCTION-1807
JUNCTION-1808
JUNCTION-1852
JUNCTION-1853
JUNCTION-1854
JUNCTION-1864
JUNCTION-1877
JUNCTION-1878
JUNCTION-1879
JUNCTION-1880
JUNCTION-1881
JUNCTION-1883
JUNCTION-1884
JUNCTION-1885
JUNCTION-1892
JUNCTION-1893
JUNCTION-1894
JUNCTION-1895
JUNCTION-1897
JUNCTION-1898
JUNCTION-2010
JUNCTION-2016
JUNCTION-2017
Possible Contamination Source Nodes

12:00 AM

Identification of Grab Sample Locations

- To reduce the number of possible sources and improve the effectiveness of the response, the water utility decides to take manual grab samples
- JUNCTION-1620 and JUNCTION-1885 are identified as the two grab sample locations



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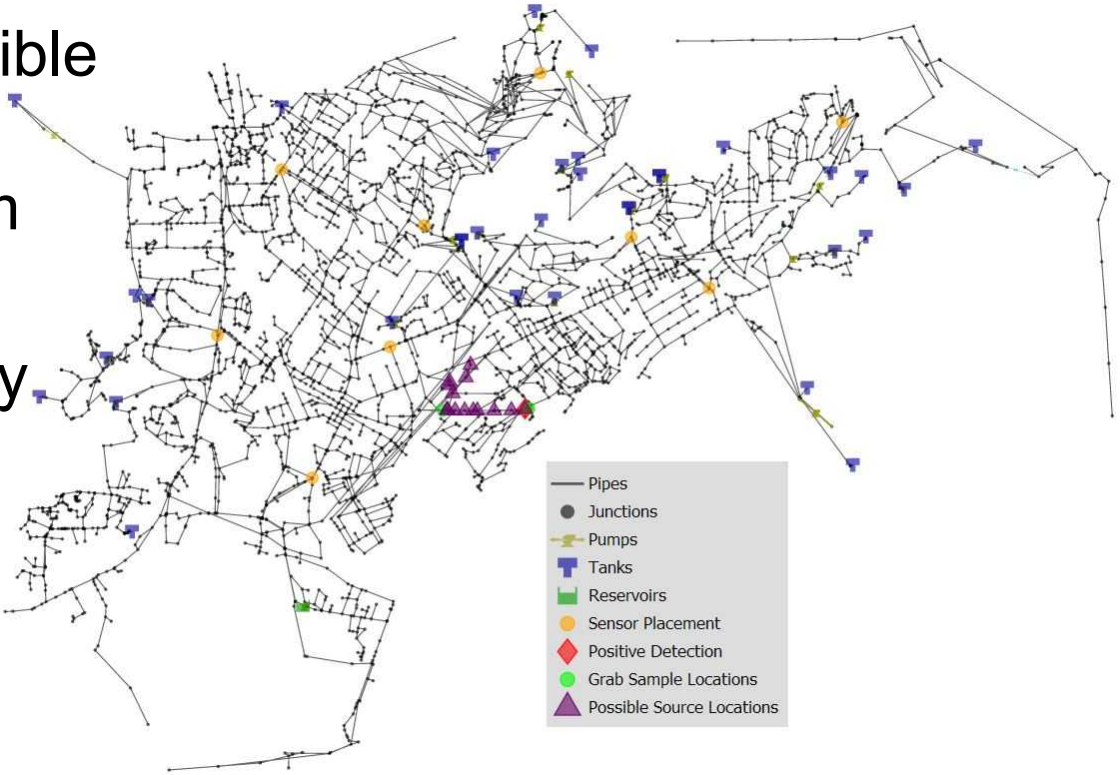
12:10 AM

Reduction of Possible Sources

- With the sensor results from the past 36 hours and two grab sample results, 14 possible sources are identified
- Use new list of possible sources for flushing optimization problem
  - Need to account for additional delay times



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Other Response Options

- Use WST to evaluate
  - Flushing at more locations, longer durations
  - Isolating sections of the next to contain contamination
  - Injecting disinfectant using existing booster stations to inactivate a biological contaminant
  - Identifying people who might have been impacted

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Conclusions

- WST can be used to help identify
  - Possible sources of contamination
  - Hydrants to flush to remove contaminated water
  - Grab sample locations to reduce number of sources
- Important to evaluate impacts of response actions before implementation

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Future Work

- Investigate approaches to reduce computational time of current optimization methods
- Perform additional simulation studies using WST to provide more strategic information to water utilities
- Incorporate additional response strategies
  - Sampling locations for confirmation and/or decontamination
  - Valve locations to isolate contaminated regions

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Water Security Toolkit v1.1

- Freely available, open source software under the revised BSD license
- Downloadable at https://software.sandia.gov/trac/wst
- Opportunities available for collaboration

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Additional Background Slides

Network-constrained Local Search (NS)

- Derivative-free local search algorithm
  - Allowable moves are to adjacent nodes
  - Provides local refinement of candidate solution
  - Valid moves include removing node location and placing any removed nodes anywhere in the network
    - Reduces to a greedy placement algorithm without initial solution
  - Convergence occurs when no improving moves remain